ELSEVIER

Atmospheric Environment 38 (2004) 5295–5304

ATMOSPHERIC ENVIRONMENT

www.elsevier.com/locate/atmosenv

A comparison of ground-level air quality data with New York State Department of Environmental Conservation monitoring stations data in South Bronx, New York

Carlos Restrepo[a,*], Rae Zimmerman[a], George Thurston[b], Jessica Clemente[b], John Gorczynski[b], Mianhua Zhong[b], Martin Blaustein[b], Lung Chi Chen[b]

[a]*Institute for Civil Infrastructure Systems, Robert F. Wagner Graduate School of Public Service, New York University, 295 Lafayette Street, 2nd Floor, New York, NY, 10012, USA*

[b]*Nelson Institute of Environmental Medicine, School of Medicine, New York University, 57 Old Forge Road, Tuxedo, NY 10987, USA*

Abstract

The South Bronx is a low-income, minority community in New York City. It has one of the highest asthma rates in the country, which community residents feel is related to poor air quality. Community residents also feel that the air quality data provided by the New York State Department of Environmental Conservation (DEC) through its network of monitoring stations do not reflect the poor quality of the air they breathe. This is due to the fact that these monitoring stations are located 15 m above ground. In the year 2001 this project collected air quality data at three locations in the study area. They were collected close to ground-level at a height of 4 m by a mobile laboratory placed in a van as part of the South Bronx Environmental Health and Policy Study. This paper compares data collected by the project with data from DEC's monitoring stations in Bronx County during the same periods. The goal of the comparison is to gain a better understanding of differences in measured air quality concentrations at these different heights. Although there is good agreement in the data among DEC stations there are some important differences between ground-level measurements and DEC data. For $PM_{2.5}$ the measured concentrations by the van were similar to those recorded by DEC stations. In the case of ozone, the concentrations recorded at ground level were similar or lower than those recorded by DEC stations. For NO_2, however, the concentrations recorded at ground level were over twice as high as those recorded by DEC. In the case of SO_2, ground level measurements were substantially higher in August but very similar in the other two periods. CO concentrations measured at ground-level tend to be 60–90% higher than those recorded by DEC monitoring stations. Despite these differences, van measurements of SO_2 and CO concentrations were well below EPA standards.

Keywords: Air pollution; Air quality; Monitoring; Asthma; Bronx County; New York

1. Introduction

The South Bronx Environmental Health and Policy Study is a collaborative project between New York University's School of Medicine and Wagner Graduate School of Public Service, and four local community

*Corresponding author.
E-mail address: cer202@nyu.edu (C. Restrepo).

1352-2310/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.atmosenv.2004.06.004

groups: The Point Community Development Corporation, We Stay/Nos Quedamos, Sports Foundation, Inc., and Youth Ministries for Peace and Justice, Inc. The main goal of the project is to study relationships between environmental issues such as air quality, human activities, such as transportation and waste transfer, and their impact on human health. The South Bronx is a predominantly low-income, minority community which for the purposes of this study was defined to comprise five community districts in the southwestern portion of Bronx County, New York. According to Census 2000 data, this area has a population of approximately 522,412 people, which represents about 40% of the total for Bronx County. About 39% of the population in this area is African-American and 60% is Hispanic. Traffic density in the area is very high. The Cross Bronx Expressway, the Bruckner Expressway and the Major Deegan Expressway, with annual average daily traffic of 75,000–150,000 vehicles all cross the South Bronx. In addition, the area has a high concentration of waste transfer stations and other commercial activities associated with high diesel truck traffic volumes (Zimmerman et al., 2002).

From the beginning of the project the community groups showed great interest in studying air quality in their community and comparing it to available data from the New York State Department of Environmental Conservation (DEC). Their interest was mainly in gaining a better understanding of air quality in the area, since later stages of the project will examine the association between air quality and asthma, which they consider to be among the top health concerns of their community. Previous studies have identified Bronx County as having the highest rates of asthma morbidity and mortality in New York City (Carr et al., 1992). Asthma affects Hispanics and African-Americans disproportionately in New York City. According to a study that assessed the influence of geography, race and ethnicity on hospital admission rates for asthma between 1989 and 1991, the average citywide annual hospital admission rate for asthma was 681/100,000 population. However, the rates for Hispanics, Blacks and Whites were 1,003, 810, and 242/100,000 population respectively (De Palo et al., 1994).

2. Methods

During the year 2001, this project collected data on air pollutant concentrations at three locations in the South Bronx. The data were collected by a mobile laboratory placed in a van. Table 1 shows the equipment used by the project to measure pollutant concentrations. The van's data are available online at the project's web page: www.nyu.edu/projects/southbronxhealth. Daily values of air pollution in New York City are provided by DEC at: www.dec.state.ny.us/website/dar/bts/airmon/sitepage2.htm. The instrumentation used by the van to collect data is the same as that used by DEC and was calibrated according to EPA federal reference methods. Information about DEC's instrumentation is found at: www.dec.state.ny.us/website/dar/bts/airmon/parametertextpage2.htm.

Table 2 shows the location of New York State Department of Environmental Conservation's (DEC) monitoring stations for which data were available for comparison to the project's van data. DEC's data are used as part of the U.S. Environmental Protection

Table 1
Characteristics of mobile laboratory

Pollutant	Instrumentation and *methodology* used by project's mobile lab	EPA Reference and/or equivalency designation	Averaging time
Sulfur dioxide (SO_2)	Thermo Environmental Instruments Model 43C SO_2 Analyzer *Pulsed Fluorescence*	EQSA-0486-060	1 h
Oxides of nitrogen nitrogen dioxide (NO_2)	Columbia Scientific Industries Model 1600 Analyzer *Chemiluminescence*	RFNA-0977-025	1 h
Carbon monoxide (CO)	Thermo Environmental Instruments Model 48C CO Analyzer *Gas Filter Correlation*	RFCA-0981-054	1 h
Ozone (O_3)	Thermo Environmental Instruments Ozone Analyzer Model 49C *UV Photometric*	EQOA-0880-047	1 h
Particulate matter	Rupprecht & Patashnick Series 1400a Ambient Particulate Monitor *Tapered element oscillating microbalance (TEOM)*	EQPM-1090-079	30 min

Source: Nelson Institute of Environmental Medicine: http://www.nyu.edu/projects/southbronxhealth/lab/interior.htm.

Agency's (EPA) Aerometric Information Retrieval System (AIRS) database. Monitoring air pollution in a dense urban environment such as New York City presents some important challenges. In general, air pollution monitoring station inlets should be exposed to air from all sides. Moreover, they should be in open areas or on roofs in order to obtain good exposure to the atmosphere (Harrison, 1999). In the case of Bronx County, such considerations, along with vandalism and security concerns, have resulted in the placement of monitoring stations 15 m above ground. Three of the four fixed-site monitoring stations are located on the rooftops of schools. This is in compliance with current U.S. regulations. According to Part 58, Appendix E of the Code of Federal Regulations (2002) the height from ground to probe for a monitoring station should be 3–15 m for SO_2, CO, O_3, and NO_2, and 2–15 m for $PM_{2.5}$. However, such placement raises the issue identified by the community groups of whether the data collected by these stations truly reflects the quality of the air residents breathe close to ground-level. The height of the mobile laboratory's intake probe used by the project is 4 m which is within the range established by the Code of Federal Regulations for these pollutants. Table 3 shows the location of the van during the three periods for which data were compared. The geographical locations where the van collected data and that of DEC's monitoring stations are shown in Fig. 1.

Table 2
NYS DEC air quality monitoring station information

Station ID	Location	Height above ground
709406	New York Botanical Garden, 200th St. at Southern Blvd.	15 m
709407	I.S. 52 681 Kelly St., off 156th St.	15 m
709408	I.S. 74 730 Bryant Ave.	15 m
709409	P.S. 154 333 E. 135th St.	15 m

Table 3
Location of the project's van in 2001

Location	Period
P.S. 154	1–29 August 2001
Hunts Point Avenue and 163rd Street	7–29 November 2001
Noble Field Park	2–31 December 2001

3. Results

The data from the van's mobile laboratory and DEC stations were compared for fine particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), and carbon monoxide (CO). The results of the data comparisons for each pollutant are described in the following sections.

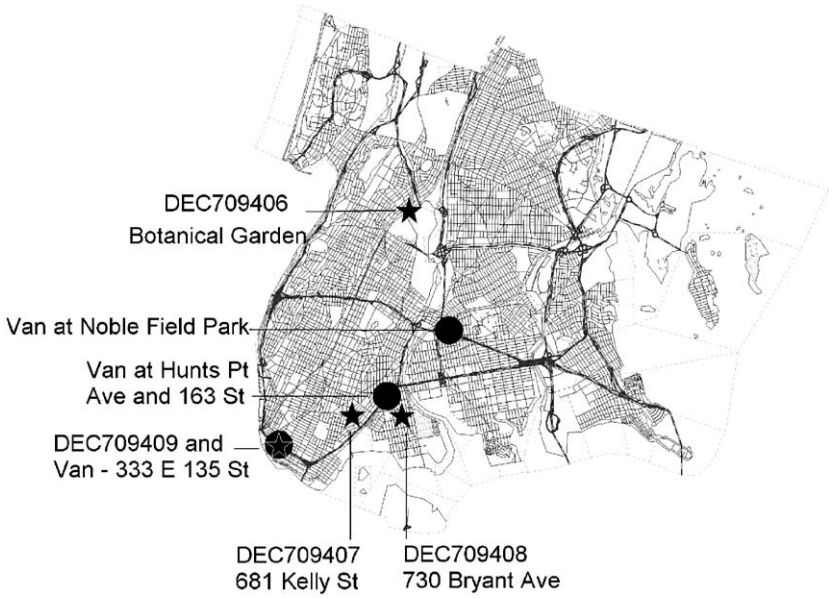

Fig. 1. Location of DEC monitoring stations and project van sampling, Bronx County, 2001.

Table 4
$PM_{2.5}$ data

Period of comparison	Station and standards	Number of daily values	Minimum	Maximum	Mean ($\mu g\,m^{-3}$)	Std. deviation	F	p
1–29 August	Van	23	8.83	51.39	25.0519	9.31496	0.010	0.990
	DEC-709408	29	8.29	53.68	24.6422	11.33561		
	DEC-709409	29	8.64	51.06	24.7600	10.18741		
9–29 November	Van	21	6.18	36.94	16.7003	7.72647	0.164	0.920
	DEC-709407	21	6.31	35.47	15.2478	7.26249		
	DEC-709408	21	5.69	39.51	15.3585	8.16313		
	DEC-709409	21	6.74	36.87	15.4539	7.55476		
5–31 December	Van	27	5.14	24.23	12.7935	5.02136	0.145	0.933
	DEC-709407	27	5.31	23.05	12.0481	4.33431		
	DEC-709408	27	5.74	25.26	12.2710	4.66355		
	DEC-709409	27	5.58	25.77	12.0423	5.22416		

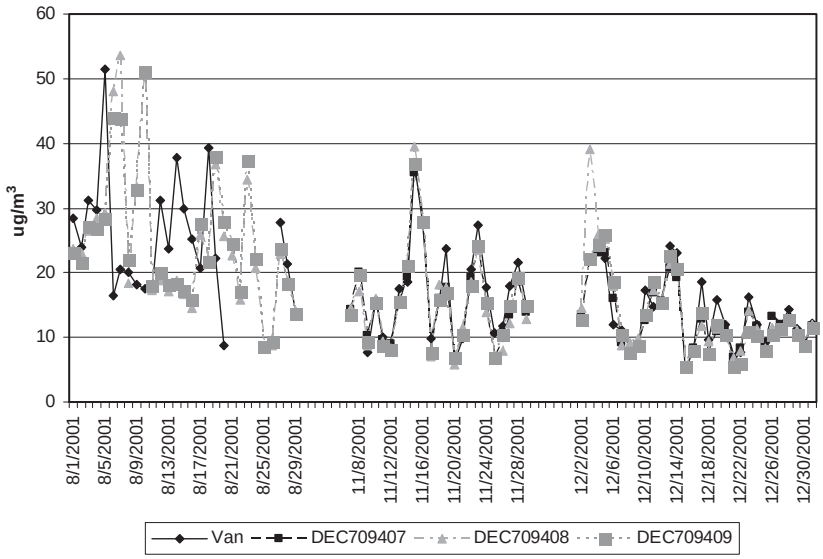

Fig. 2. Comparison of $PM_{2.5}$ data, 24-h averages, 2001.

3.1. Fine Particulate Matter ($PM_{2.5}$)

This section compares the daily average concentrations of $PM_{2.5}$ recorded by the project's van with those of DEC monitoring stations located in Bronx County. Table 4 and Fig. 2 summarize the data. The data shown are 24-h averages. The recorded concentrations do not exceed EPA's 24-h standard, which is currently set at $65\,\mu g\,m^{-3}$ (USEPA, 2002). The measurements do not suggest that the van's data are significantly higher than those of DEC stations in other parts of Bronx County. Perhaps the most relevant comparison during the first period is with station 709409, which is also located at P.S. 154, but 15 m above ground. The concentrations measured by the van were higher that those recorded by station 709409 for some days but lower for others. A one-way ANOVA was carried out using SPSS to test the hypothesis that the sample means are the same in each set of data. The results of the F tests are shown in the last two columns of Table 4. In all cases, the tests suggest that the hypothesis that mean $PM_{2.5}$ concentrations between project and DEC stations are equal should be accepted. It appears that $PM_{2.5}$ concentrations are pretty uniform in the South Bronx.

3.2. Sulfur Dioxide (SO_2)

The van's measurements of SO_2 concentrations are compared to data from DEC's monitoring stations in Table 5 and Fig. 3. In general, the data for SO_2 are similar in terms of day to day changes. There is close correspondence between the concentrations measured

Table 5
SO_2 data

Period of comparison	Station and standards	Number of daily values	Minimum	Maximum	Mean (ppm)	Std. deviation	*F*	*P*
1–29 August	Van	22	0.00	0.04	0.0192	0.00674	76.877	0.000
	DEC-709406	23	0.00	0.02	0.0057	0.00303		
9–28 November	Van	20	0.01	0.04	0.0207	0.01005	2.276	0.112
	DEC-709406	20	0.00	0.03	0.0150	0.00789		
	DEC-709407	20	0.00	0.04	0.0158	0.00930		
2–31 December	Van	30	0.01	0.03	0.0173	0.00610	2.946	0.058
	DEC-709406	30	0.01	0.03	0.0140	0.00511		
	DEC-709407	30	0.01	0.03	0.0152	0.00483		

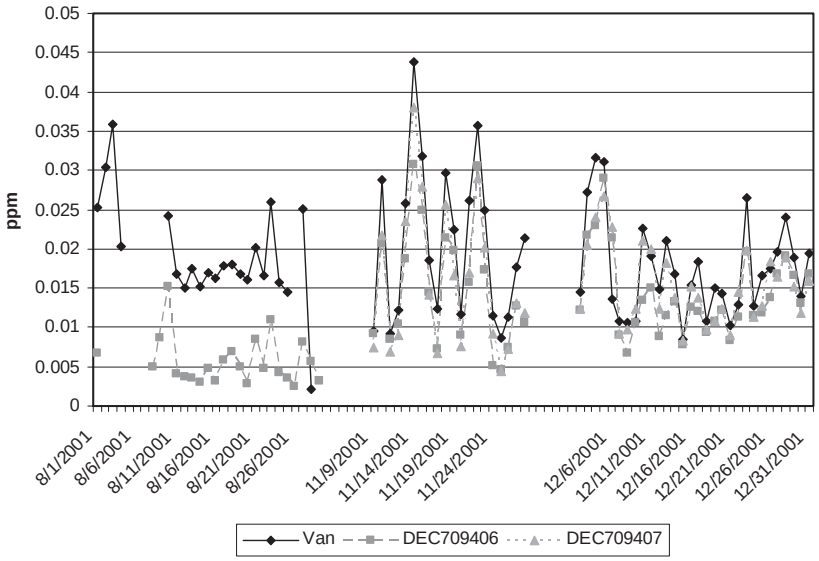

Fig. 3. Comparison of SO_2 data, 24-h averages, 2001.

by the two DEC stations. The data recorded by the van are generally higher. However, the van's measured concentrations are still substantially lower than EPA's 24-h average standard, which is currently 0.14 ppm (USEPA, 2002). The most pronounced difference is for the first comparison, when the van was located at P.S. 154. During this period, August 1–29, the van's measurements are two to three times higher than DEC station measurements. DEC data show a more typical seasonal variation for this pollutant. DEC values for August are much lower than those recorded during November and December. In the winter, SO_2 concentrations reflect fuel combustion associated with space heating and these sources tend to be uniformly distributed (Lipfert and Hammerstrom, 1992). An additional source of SO_2 is diesel vehicles, which are not uniformly distributed in Bronx County. The discrepancy in the data may reflect higher traffic density for diesel vehicles at P.S. 154, where the van was located in August, relative to the location of DEC station 709406, which is located close to the New York Botanical Garden. Although DEC has a monitoring station located at P.S. 154, that station did not measure SO_2 concentrations. A one-way ANOVA was carried out to test the hypothesis that the means for the three sets of data are equal. The results of the F tests and their significance values are shown in the last two columns of Table 5. Consistent with the description provided above, the tests suggest that the hypothesis should be rejected for the August data but not for the other data sets.

3.3. Nitrogen Dioxide (NO_2)

The comparison of NO_2 data is available for two periods in 2001. The data are summarized in Table 6 and shown in Fig. 4. The van measurements are much higher than those recorded by DEC stations. During the second

Table 6
NO_2 data

Period of comparison	Station	Number of daily values	Minimum	Maximum	Mean (ppm)	Std. deviation	*F*	*p*
16–28 November	Van	13	0.06	0.10	0.0753	0.01234	116.69	0.000
	DEC-709406	13	0.02	0.04	0.0328	0.00706		
2–31 December	Van	29	0.05	0.11	0.0734	0.01693		
141.509	0.000							
	DEC-709406	30	0.02	0.05	0.0288	0.00697		
	DEC-709407	22	0.02	0.05	0.0275	0.00704		

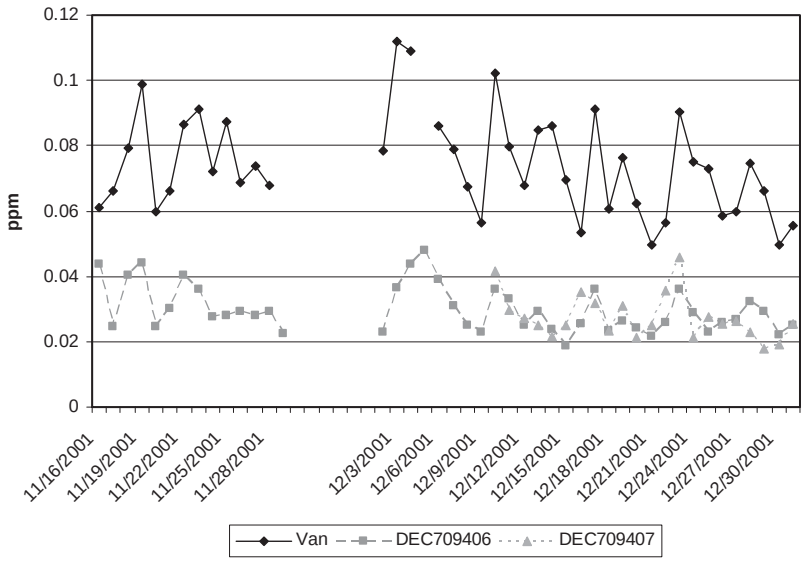

Fig. 4. Comparison of NO_2 data, 24-h averages, 2001.

Table 7
Average daily measurements of NO_2 concentrations, DEC 2001

DEC station	No. of observations	Minimum	Maximum	Mean (ppm)	Std. Deviation
709406	265	0.01	0.06	0.0312	0.01033
709407	242	0.00	0.06	0.0316	0.01006

period the concentrations measured by two DEC stations in Bronx County are similar to each other but significantly lower than the van measurements. The results of a one-way ANOVA (F tests and their significance values) are shown in the last two columns of Table 6. The tests suggest that the hypothesis that the means are equal should be rejected for both the November and December data. The standard established by EPA for NO_2 is a one-year average currently set at 0.053 ppm (USEPA, 2002), so it is not possible to compare it to these data. If the van's measurements are representative of NO_2 concentrations at ground-level throughout the year EPA's standard would be exceeded by a wide margin. This is likely to be the case since ambient outdoor concentrations of NO_2 generally show little seasonal variation in urban areas (Ackermann-Liebrich and Rapp, 1999). Table 7 and Fig. 5 show the average daily values of NO_2 measured by DEC's monitoring stations during 2001, and there does not appear to be much seasonal variation.

3.4. Ozone (O_3)

The available ozone measurements are summarized in Table 8 and shown in Fig. 6. In order to compare the data to an EPA standard, the daily 1-h maximum values

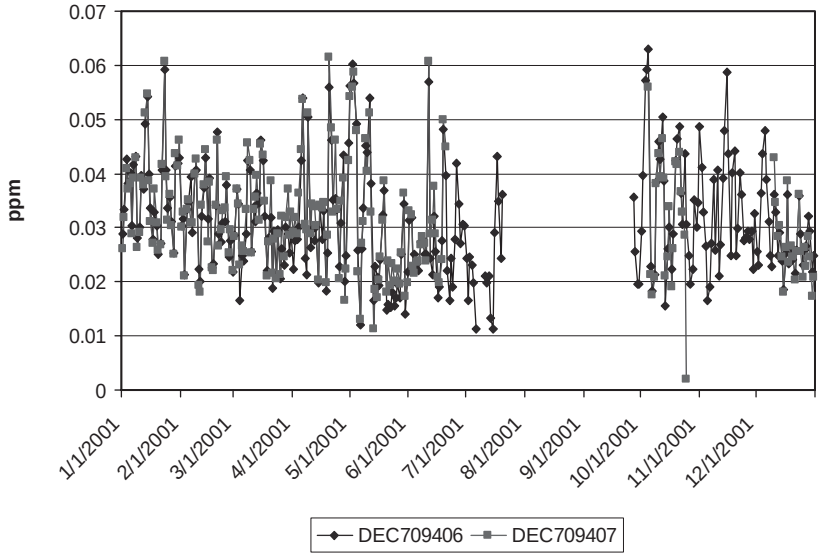

Fig. 5. Average daily values of NO_2 concentrations, 2001.

Table 8
O_3 data

Period of comparison	Station	Number of daily values	Minimum	Maximum	Mean (ppm)	Std. deviation	*F*	*P*
1–29 August	Van	23	0.03	0.07	0.0421	0.01461	20.428	0.000
	DEC-709406	23	0.03	0.09	0.0608	0.01527		
9–29 November	Van	21	0.00	0.02	0.0112	0.00693	3.219	0.047
	DEC-709406	21	0.01	0.03	0.0163	0.00729		
	DEC-709407	21	0.01	0.03	0.0160	0.00779		
2–31 December	Van	30	0.00	0.03	0.0111	0.00597	0.229	0.796
	DEC-709406	30	0.00	0.02	0.0127	0.00552		
	DEC-709407	30	0.00	0.02	0.0113	0.00563		

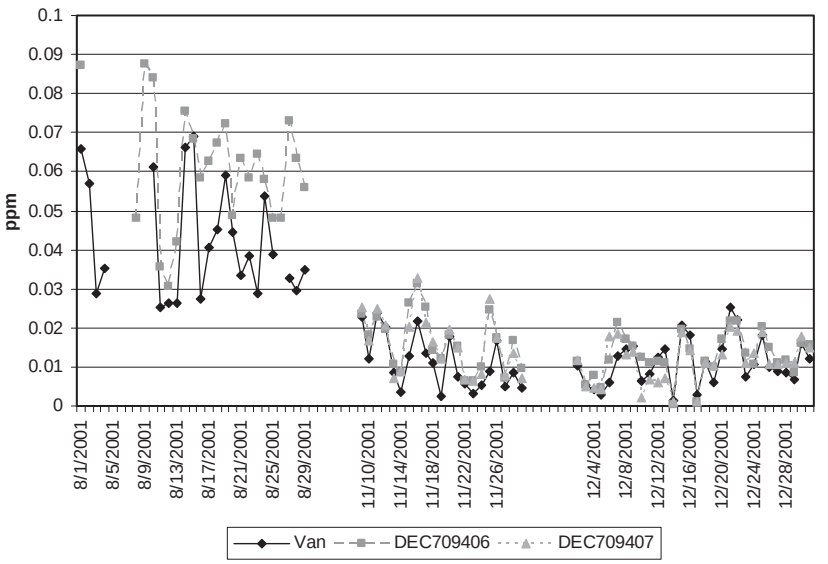

Fig. 6. Comparison of O_3 data, daily 1-h maxima, 2001.

were selected. The values recorded by the van are similar or lower than those recorded by DEC stations 709406 and 709407. The last two columns of Table 8 show the F value and significance of a one-way ANOVA to test the hypothesis of equal means. The results suggest that the hypothesis should be rejected for the August and November data, when the van measurements were lower than those recorded by DEC's stations, but not for December, when both the van and DEC recorded similar values. None of the maximum one hour concentration values during the periods under consideration, for either the van or the DEC stations, exceed EPA's 1-h standard, which is currently 0.12 ppm (USEPA, 2002). Ozone is a regional pollutant so DEC's stations which are located 15 m above ground may pick up regional concentrations of ozone better than ground level measurements. These results also show the inverse relationship expected between NO_2 and O_3 concentrations. Nitrogen oxide (NO) generated by vehicles and power stations reacts with ozone to form NO_2 and O_2 (Derwent, 1999). Hence, lower concentrations of O_3 are expected to be found closer to ground-level.

3.5. Carbon Monoxide (CO)

As with ozone, the data for carbon monoxide are presented as daily maximum 1-h concentrations. This allows the data to be compared to EPA's 1-h CO standard, which is currently 35 ppm (USEPA, 2002). The data are summarized in Table 9 and shown in Fig. 7. DEC station 709406 is the only station which monitored CO in Bronx County during 2001. These comparisons suggest that the highest carbon monoxide 1-h averages recorded each day by the project's van are generally higher than those recorded by DEC station 709406. The last two columns of Table 9 show the F values and significance of a one-way ANOVA to test the hypothesis that the means are equal. The results suggest that the hypothesis should be rejected in all cases. CO concentrations in Bronx County are closely related to

Table 9
CO data

Period of comparison	Station and standards	Number of daily values	Minimum	Maximum	Mean (ppm)	Std. deviation	F	p
1–29 August	Van	23	1.05	2.75	1.9624	0.46472	40.971	0.000
	DEC-709406	23	0.70	2.43	1.1691	0.37052		
9–29 November	Van	21	1.05	5.53	2.5637	1.21474	9.501	0.004
	DEC-709406	21	0.71	4.91	1.5124	0.98350		
2–31 December	Van	30	0.78	5.54	2.3904	1.24401	18.048	0.000
	DEC-709406	30	0.54	3.93	1.2458	0.79377		

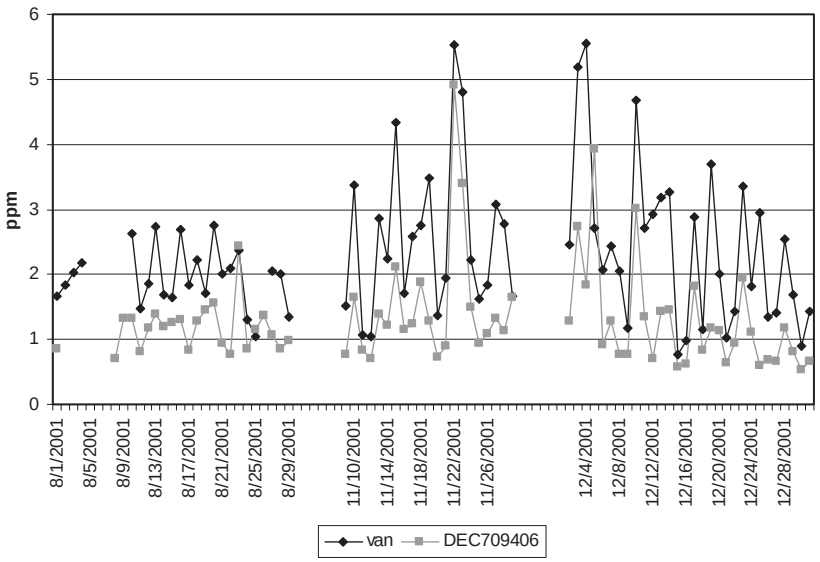

Fig. 7. Comparison of CO data, daily 1-h maxima, 2001.

traffic density. The typical spatial scale for CO monitoring is considered to be only about 0.1 km and there can be important local gradients (Lipfert and Hemmerstrom, 1992). Hence, the difference in concentrations measured by the project's van and by DEC stations may also reflect differences in traffic concentrations. DEC station 709406 is located by the New York Botanical Garden, where traffic density may be lower than the sites where the van took measurements. Despite these differences, all measured 1-h concentrations of CO in these three periods were well below EPA's 1-h standard for both the van and DEC data sets.

4. Discussion and Conclusions

The measurements of ambient pollution concentrations made by the project's mobile laboratory are similar to those recorded by DEC stations located 15 m above ground for some pollutants but substantially different for others. For $PM_{2.5}$ the ground-level measurements are similar in value and trend with those of DEC stations. For example, during the period November 7–29, 2001, the average daily concentration recorded by the van was $16.70\,\mu g\,m^{-3}$. The average values for three DEC monitoring stations in the area ranged between 15.39 and $15.54\,\mu g\,m^{-3}$. The values are below EPA's current 24-h average standard. The similarities in the observed measurements at ground level and 15 m above ground reflects the fact that $PM_{2.5}$ is a regional pollutant with many background sources outside the area.

In the case of ozone, the concentrations recorded at ground level were generally lower or similar to those recorded by DEC stations. During the period November 7–29, the average daily concentration of O_3 recorded by the van was 0.0035 ppm. Two DEC stations in the area recorded daily averages of 0.0059 and 0.0062 ppm. In order to compare the data with an EPA standard, the highest 1-h average value was selected each day of the period and compared to DEC data. As with the daily averages, the daily maximum 1-hour averages recorded by the project's van were generally lower than those recorded by the DEC stations. During the periods for which data were collected both the van's and DEC's measured concentrations were below EPA's standard. As with $PM_{2.5}$, many of the sources of the pollutants that result in the formation of ozone are outside the study area and ozone is also considered a regional pollutant.

For the other pollutants the concentrations measured by the project were substantially higher than those recorded by DEC's monitoring stations. The sources of these gaseous pollutants are more localized, and in the case of NO_2 and CO they are closely related to traffic. In the case of SO_2, ground-level measurements recorded by the project's van were substantially higher than DEC measurements in August, when they were about 40% higher, but similar in November and December. However, the van's as well as DEC's data suggest concentrations that are well below EPA's 24-h average standard for SO_2. Similarly, CO concentrations measured at ground-level tend to be higher than those recorded by DEC's stations. As with ozone, 1-h average maximum values were selected each day in order to compare the data with EPA's 1-hour standard. Both the van's and DEC's measurements suggest concentrations of CO that are well below EPA's standard.

The most significant difference between ground-level measurements taken by the project's van and those taken by DEC stations located 15 m above ground is for NO_2. Daily average concentrations for this pollutant recorded at ground-level are over twice as high as those recorded by DEC stations. If the van's data are representative of concentrations of NO_2 in the area for the whole year, EPA's annual standard would be exceeded. This is likely to be the case since NO_2 concentrations show little variation between summer and winter and tend to be spatially homogeneous in urban areas. Indoor NO_2 concentrations in the South Bronx may also be relatively high since outdoor NO_2 penetrates indoor areas with a typical outdoor-to-indoor ratio of 0.5 (Ackerman-Liebrich and Rapp, 1999). If such a ratio holds in the South Bronx, indoor concentrations of NO_2 may be around 0.037 ppm. Given these results, it appears that the concerns expressed by community groups regarding pollution levels at ground-level relative to DEC measurements 15 m above ground are well founded in the case of NO_2.

According to the literature, NO_2 is believed to be partially responsible for a number of health problems (Ackerman-Liebrich and Rapp, 1999). The most relevant health effect in this particular area may be the association between NO_2 and asthma. As mentioned earlier, Bronx County has the highest rates of asthma hospitalizations and mortality in New York City and it is a major health concern among community residents. Pulmonary function is known to change in asthmatic individuals when exposed to concentrations of NO_2 between 0.2 and 0.5 ppm. The annual National Ambient Air Quality Standard (NAAQS) for NO_2 was set at 0.053 ppm because it was estimated that if that concentration was attained in a given area, the occurrence of 1-hour concentrations greater than 0.2 ppm would be unlikely (USEPA, 1995).

More recent evidence suggests there is an association between exposure to NO_2, viral infections and asthma exacerbation. A prospective study carried out in Southampton, United Kingdom, used a cohort of 114 asthmatic children aged between 8 and 11 years in order to assess the relation between NO_2 exposure in the week before or after upper respiratory-tract infection and the severity of asthma exacerbation in the week after the

start of an infection. The authors conclude that high exposure to NO_2 the week before the start of a respiratory viral infection is associated with an increase in the severity of a resulting asthma exacerbation (Chauhan et al., 2003).

Although it is clear that DEC has sited its monitoring stations in compliance with current regulations, the measurements of NO_2 concentrations at ground-level made by the project's van suggest that the use of DEC data in health studies could underestimate human exposures to this pollutant in the South Bronx. Moreover, evidence from a number of health studies suggests that this pollutant could pose important health risks in the project area. More research should be carried out to ensure that ground-level concentrations of NO_2 in this area are within EPA's standard. A future research direction should be to take measurements at the same location as DEC's stations in order to make more direct comparisons between measurements at various heights and 15 meters above ground in order to obtain more detailed information about the vertical profile of NO_2. Both street level measurements provided by the van and broader areawide measurements provided by the DEC stations are valuable measures of air quality in the South Bronx, and a means to use both results with appropriate comparisons is an important basis for policy. Such comparisons would have important policy implications if the ground-level measurements are found to be consistently higher than DEC station measurements. Since NO_2 in the area is produced mostly by high traffic densities associated with heavy concentrations of waste transfer stations and other commercial and industrial activities, such findings would help policymakers make better decisions about the siting of facilities that impact traffic patterns and air quality in the area.

Acknowledgements

Supported by US EPA Agreement X-982152. The project has benefited enormously from the participation of four South Bronx community groups: The Point Community Development Corporation, We Stay/Nos Quedamos, Sports Foundation, Inc., and Youth Ministries for Peace and Justice, Inc. This work was also supported by the following grants: NIEHS Center of Excellence (ES00260) and US EPA PM Health Research Center (R827351).

References

Ackermann-Liebrich, U., Rapp, R., 1999. Epidemiological Effects of Oxides of Nitrogen, Especially NO_2. In: Holgate, S., Samet, J., Koren, H., Maynard, R. (Eds.), Air Pollution and Health. New York, Academic Press, pp. 561–584.

Carr, W., Zeitel, L., Weiss, K., 1992. Variations in asthma hospitalizations and deaths in New York City. American Journal of Public Health 82 (1), 59–65.

Chauhan, A., Inskip, H., Linaker, C., Smith, S., Schreiber, J., Johnston, S., Holgate, S., 2003. Personal exposure to nitrogen dioxide (NO_2) and the severity of virus-induced asthma in children. The Lancet 361, 1939–1944.

Code of Federal Regulations. 2002. Environmental Protection Agency. Appendix E to Part 58 – Probe and Monitoring Path Siting Criteria for Ambient Air Quality Monitoring, 40 CFR (Chapter I). (7-1-02 ed). pp. 273–285.

De Palo, V., Mayo, P., Friedman, P., Rosen, M., 1994. Demographic Influences on Asthma Hospital Admission Rates in New York City. Chest 106 (2), 447–451.

Derwent, R., 1999. Atmospheric Chemistry. In: Holgate, S., Samet, J., Koren, H., Maynard, R. (Eds.), Air Pollution and Health. New York, Academic Press, pp. 51–62.

Harrison, R., 1999. Measurements of Concentrations of Air Pollutants. In: Holgate, S., Samet, J., Koren, H., Maynard, R. (Eds.), Air Pollution and Health. New York, Academic Press, pp. 63–82.

Lipfert, F., Hammerstrom, T., 1992. Temporal Patterns in Air Pollution and Hospital Admissions. Environmental Research 59, 374–399.

United States Environmental Protection Agency (USEPA), 1995. Review of the National Ambient Air Quality Standards for Nitrogen Dioxide Assessment of Scientific and Technical Information. Office of Air Quality Planning and Standards (OAQPS) Staff Paper.

United States Environmental Protection Agency (USEPA), 2002. National Ambient Air Quality Standards (NAAQS). <http://www.epa.gov/air/criteria.html> (accessed 30, 2003).

Zimmerman, R., Restrepo, C., Hirschstein, C., Holguín-Veras, J., Lara, J., Klebenov, D., 2002. South Bronx environmental studies, public health and environmental policy analysis: Final Report for Phase I. <http://www.epa.gov/air/criteria.html> (accessed date 30, 2003).